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A simple self-registering auxanometer.

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(WITH PLATE V.)

The various forms of self-registering auxanometers used in botanical laboratories are more or less complicated and costly instruments. Such instruments as are used by Sachs, Wiesner, Baranetzky, Pfeffer, and others, vary considerably in their construction and utility. One of the best auxanometers for general purposes that has been devised is that of Baranetzky. A modified form of this apparatus is used by Pfeffer, a figure and description of which is given in his Pflanzenphysiologie.[1]

The multiplying apparatus, which, however, is the most important part of an auxanometer, consists of two grooved wheels of different radii that are fixed to a horizontal axis which revolves on delicate bearings. The large wheel has a radius of 100 mm., and the small one of usually about 12.5 mm., thus giving an enlargement of eight times; over the small wheel there passes a thread, one end of which is connected with the plant, the other to a weight of sufficient size to cause the wheel to respond freely to the movements of the plant. Each movement of the small wheel is communicated to the large wheel which supports the pen and a compensating weight. This apparatus can be used with any form of a registering cylinder; perhaps the most convenient for general purposes is the electric drum that registers in steps.

The accompanying figure shows a simple and inexpensive auxanometer used by the writer, which can be easily constructed by any one. The enlarging apparatus consists of a hand balance, such as is used in every laboratory. The arrangement is as follows: To one of the balance arms there is attached a very light though rigid straw, to the free end of the straw there is fastened, by means of sealing wax, a fine pin of spring brass

[1] See also Goodale's Physiological Botany, p. 383.

wire that serves as a pen. The end of the wire or pen is hammered out very thin, and cut with a pair of scissors to a delicate point. A length of one or two cm. near the base is also flattened to lessen the rigidity of the wire, that the point may offer much less resistance when in contact with the cylinder. It is necessary that the pen should be long and sufficiently curved, so that the straw itself does not come in contact with the cylinder.

To the other balance arm the plant is connected by means of a thread fastened to the under side of the scale. Before attaching the plant, however, enough weight is added to the left hand scale to balance the weight of the straw, after which a small weight (in our experiments .04 gm.) is added to the right hand scale to produce the proper deflection, which should be equal to at least one-half the length of the registering cylinder. The amount of deflection can be determined by a paper protractor fastened at the top of the balance. If now we have a deflection equal to one-half the length of the registering cylinder, and the balance arm be placed at a corresponding point above the horizontal position, the pen will have an amplitude of motion equal to the whole length of the cylinder. When the balance arm is in this latter position the plant is attached, and it is evident now that the tension on the thread would not be .04 gm., but .08 gm. It is desirable that the straw and pen should be exceedingly light, so as to interfere as little as possible with the sensitiveness of the balance.

Such an adaptation of the hand balance answers as a simple substitute for the more expensive multiplying appliances; moreover it possesses a greater degree of sensitiveness, although, as we have seen, the tension is not constant. For example, it may be .08 gm. in the beginning of the experiment, and only .04 gm. when the balance arm is in the horizontal position, but this variation we believe is practically unimportant with such small weights. The original apparatus of Sachs required a weight or tension of 20 gm.; that of Wiesner of 7 to 10 gm.; and the apparatus used by Pfeffer, even when compensated as fine as possible, must have a tension of 1.5 gm.; in general, however, this apparatus is used with a tension of 3 to 10 gm.

It is a well known fact that even a tension of a few grams affects the normal growth of a plant; notwithstanding this

fact, the relative growth curve produced by a large tension is correct, provided the first hourly registrations be neglected.

The registering apparatus consists of a cheap nickel clock costing seventy five cents. The minute hand is removed from its spindle and a piece of thin metal carrying the cylinder is put on instead; one end of this piece of metal is pointed and of sufficient length to answer as a substitute for the minute hand; the other end supports the cylinder and is bent outwardly, for the purpose of having the latter stand out some distance from the dial. At its point of attachment to the minute hand spindle it is considerably thickened, and the hole is made of sufficient size to allow the piece of metal to be driven on firmly. The cylinder consists of one turn of ordinary glazed paper, blackened on one side over a lamp, and having a length of about 36 cm. and a diameter of 2 cm.; it is fastened to the metal by means of soft wax. The cylinder makes a revolution once every hour, and by so doing the growth of the plant is registered by a series of parallel lines. For its successful revolution it is important that all the parts should be exceedingly light. The clock used by us was not in the least affected by the weight of the cylinder, and was capable of running 30 hours without re-winding. If, however, the cylinder is very large there is a possibility of the spindle slipping on its axis, which would prevent it from revolving. In case this should happen, or it should be desired to use even a larger cylinder, the difficulty is easily remedied by attaching a projecting rod supplied with an adjustable compensating weight to the other end of the piece of metal, so that its centre of gravity can be made to coincide with the axis of rotation; by careful compensation a weight of considerable size can be made to revolve successfully.

In a permanent apparatus a clamp provided with clips to fasten the cylinder and for the easy removing of the same from the spindle could be advantageously substituted for the piece of metal described above. If one wishes to obtain a continuous curve of growth the clock can be placed horizontally and a disk of metal be constructed so as to slip over the hour hand arbor. A cylinder of metal, wood, or even a glass-jar, covered with smoked glazed paper, or millimeter-ruled paper, can be placed upon the disk to record the growth. With millimeter-ruled paper it is necessary, of course, to substitute an ink pen for the metal one.